

CHANGES IN RIPARIAN VEGETATION ALONG THE COLORADO RIVER AND RIO GRANDE, COLORADO

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ABSTRACT—Changes in vegetation including area occupied, canopy cover, and maturity class of cottonwoods (*Populus* spp.) within lower-elevation zones of the Colorado River and Rio Grande in Colorado were monitored over 25- and 37-year intervals, respectively, using photo-interpretative methods. Estimated loss of cottonwoods along the Colorado River was 2 ha/km (-17.5%), and remaining stands had become more open and older. Cottonwoods along the Rio Grande increased 1.6 ha/km (9.3%) with minor canopy cover and maturity class changes. Area occupied by shrubs and river channel changed little along the Colorado River, but declined along the Rio Grande. Loss of hay meadow occurred along both rivers, whereas developed land increased along the Colorado River and farmland increased along the Rio Grande. Wildlife habitats along the Colorado deteriorated much more rapidly than those along the Rio Grande during monitored intervals.

Key words: riparian, Colorado, inventory, cottonwood, *Populus* spp., wildlife habitat

Riverine systems in the Great Basin and southwestern United States are important habitats for resident and migratory wildlife (Anderson and Ohmart 1980, Hunter et al. 1985). Two major river systems (Colorado and Rio Grande) in the southwestern United States originate within Colorado. While substantial work has been conducted to identify wildlife use and to manage riparian habitats in lower reaches of these river systems (Stevens et al. 1977, Anderson et al. 1978, Anderson and Ohmart 1980, 1985, Swenson and Mullins 1985), little information has been published from studies conducted near the headwaters of these rivers.

The cottonwood-willow (*Populus-Salix*) riparian ecosystem along Colorado's major rivers has the highest wildlife species richness and density in the state (Beidleman 1978, Fitzgerald 1978, Hoover and Wills 1984) and is used by 283 species of vertebrate wildlife. However, most studies have centered on the South Platte River in northeastern Colorado (Grail and Bissell 1978). Wildlife values of riparian habitats along streams and rivers in the mountainous western two-thirds of Colorado have received little study. Among ecosystems in mountainous areas, cottonwood-willow riverbottoms usually possess high values for resident and migratory wildlife (Schupp 1978, Thomas et al. 1979,

Melton et al. 1984). Awareness of these values has increased in recent years along with concern for increasing activities in, and degradation of, these critical wildlife zones (Windell 1980). These habitats are of special concern in mountainous areas because valleys are frequently narrow and centers of human activity.

Before attempting to manage riparian vegetation for wildlife, it is necessary to learn whether these habitats are declining in ability to sustain species richness and abundance. This paper assesses recent changes and status of riparian vegetation along the Rio Grande and Colorado River in southern and western Colorado.

STUDY AREA

Lower-elevation zones of the Rio Grande and Colorado River in Colorado were selected for study (Fig. 1, Table 1). The Colorado River and its tributaries drain about 46,196 km² of western Colorado (Ugland et al. 1984, Vol. 2). The Colorado River is confined to relatively narrow valleys until it is joined by the Gunnison River near Grand Junction where the valley broadens with reduced stream gradient. It leaves the state with flows approximately 75% greater than at the upstream end of the study area (Table 1).

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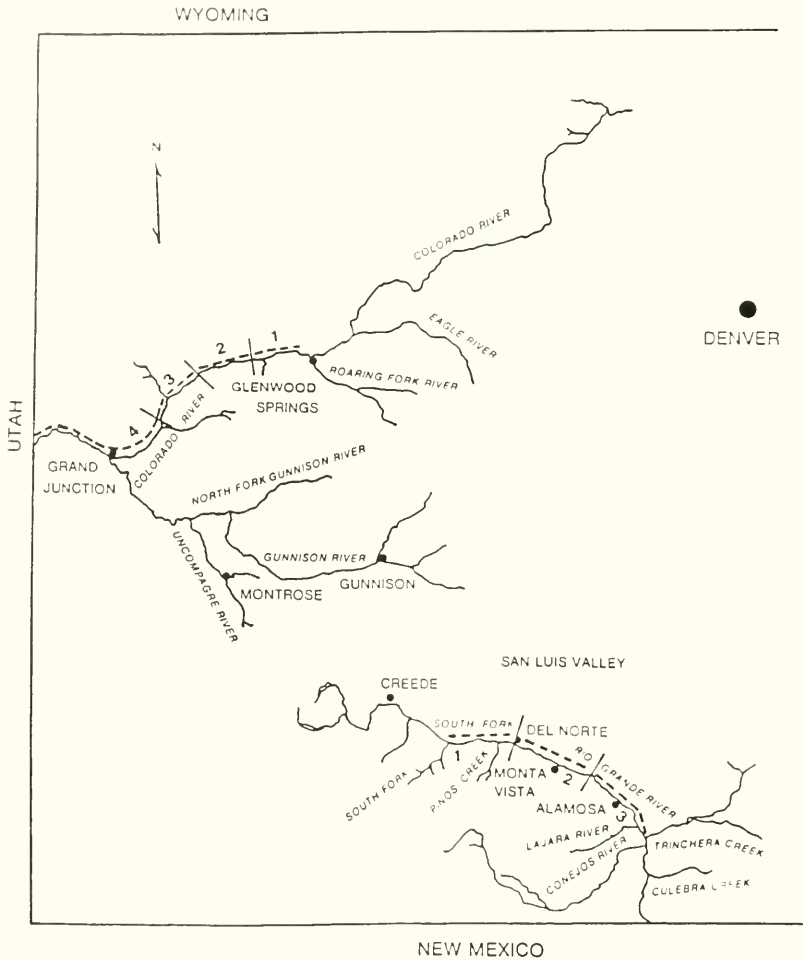


Fig. 1. Colorado River and Rio Grande with inventoried portions (—) and segments (|) in western and south central Colorado.

TABLE 1. Characteristics of variables measured along the Colorado River and Rio Grande, Colorado.

Variable	Colorado River	Rio Grande
\bar{x} sampling interval, yrs ^a	25.0	36.8
Distance sampled, km ^b	167.3	117.4
Sample units	21	20
\bar{x} ha/sample unit	57.0	163.2
Sampling intensity, %	20	27
Elevation, m		
upper	1529	2438
lower	1372	2286
\bar{x} daily stream flow, m ³ s		
upper	100.5	25.3
lower	175.5	7.0

^aAerial photos were from 1941 to 1973-83 Rio Grande^a and from 1951-57 to 1980 Colorado River.

^bLinear distance was measured at the center of the river channel.

The Rio Grande drains approximately 19,194 km², of which 7612 km² is within a closed basin in south central Colorado (Ugland et al. 1984, Vol. 1). River flow originates primarily in the San Juan Range with lesser amounts from the Sangre de Cristo Range. The river enters the western part of the San Luis Valley, a high-elevation (2286–2438 m) park, and travels through farmed areas for approximately 100 km (where most stream flows are used for irrigation [Table 1]) before entering a canyon that extends into New Mexico.

Harrington (1954) noted that narrowleaf cottonwoods (*P. angustifolia*) dominate along the Rio Grande and upper portions of the Colorado River, whereas lanceleaf cottonwoods

(*P. acuminata*) occur sparsely over a slightly broader elevation range. Rio Grande cottonwoods (*P. wislizeni*) dominate at lower elevations along the Colorado River. Willows are the primary shrubs along the Rio Grande and upper portion of the Colorado River giving way to tamarisk (*Tamarix gallica*) at lower elevations along the latter (plant names follow Harrington [1954]).

METHODS

Approximately 167 km of the Colorado River and 117 km of the Rio Grande were selected for study, and respectively stratified into four and three segments (strata) based on empirical assessments of vegetation (area occupied by cottonwoods, plot width, etc.; Fig. 1). Segments (numbered from upstream to downstream; Fig. 1) were used to distribute random sample units (linear 1.61-km river tracts) more uniformly along the rivers. Twenty sample units were distributed along the Rio Grande, whereas the Colorado River study area contained 21. An electronic planimeter, positioned at mid-channel on U.S. Geological Survey topographic maps, was used to delineate the randomly selected 1.61-km (river mile) sample units. Width of sample units varied and was based on flood plain width, primarily encompassing natural riparian vegetation readily discerned on aerial photos (some adjacent cropland and grassland were included).

The earliest (scale 1:20,000) and most recent (scale 1:40,000) aerial photos available (U.S. Department of Agriculture) were acquired for each sample unit to yield changes over time. The same area was inventoried within each sample unit during both early and recent intervals to assess changes. Earliest aerial photos were from 1941 and the most recent photos were from 1973 through 1983 for the Rio Grande. Those for the Colorado River were from 1951-57 (early) and 1980 (recent).

Interpretative analyses of aerial photos were contracted to the Colorado State Forest Service. Vegetation types, including trees (primarily cottonwoods), shrubs (tamarisk [Colorado River] and willow), hay meadows, grasslands, agriculture (farmland), developed (roads, towns, etc.), river, standing water, and unvegetated (sandbars) were delineated on acetate overlays using a stereoscope. River and unvegetated were combined as river channel. Minor vegetation

types (<1% of total area) were omitted. The area per vegetation type was recorded to 0.1 ha using an electronic planimeter. On-site inspections were conducted within several plots along both rivers to verify that photo interpretation was accurately assessing cottonwood stand maturity, canopy cover, and vegetation types. Photo interpretation accuracy approximated 95%.

Maturity classes (trunk diameter) were estimated from tree crown size using photo interpretation. The relationship between trunk diameter and tree crown size was based on previous sampling of cottonwoods along the South Platte River in Morgan County, Colorado (Getter 1977). A close relationship ($r^2 = .81$) between tree crown size and trunk diameter at breast height (dm dbh) was indicated. However, data relating dbh to tree age were lacking, as increment boring to estimate age of cottonwoods did not yield satisfactory age data. Maturity classes included stands dominated by trees <1.5, 1.5-4.0, 4.1-7.6, and >7.6 dm dbh. Stands of trees were classified by canopy cover as open (10-35%), intermediate (36-55%), and closed (>55%).

Changes in stands of cottonwoods from early to recent photos were analyzed using paired *t* tests appropriate for stratified (segment) samples based on the hypothesis that mean change was zero. Initial tests included analyses of individual maturity/canopy-cover classes; however, sample sizes were inadequate to yield meaningful results. Therefore, maturity-class data for pooled canopy cover classes and canopy-cover data for pooled maturity classes are presented. In addition, early to recent changes were presented, where canopy cover and maturity classes were partitioned. Changes for other cover types were analyzed using paired *t* tests; ANOVA was used to detect differences among segments. Mean comparisons were considered significant at $P \leq .05$.

RESULTS

Colorado River

Estimated loss of cottonwood stands along the Colorado River was 1.9 ha/km sample unit (17.5%; Table 2). Losses in the upper segment (Fig. 1), where cottonwoods initially averaged only 2.2 ha/km, were >90% (Table 3). Area occupied by cottonwoods was highest in segment 2 where they declined 4.4 ha/km. Within downstream segments, cottonwoods averaged

TABLE 2. Area occupied (\bar{x} ha/km) by vegetation/land-use type during early and recent intervals along the Colorado River and Rio Grande, Colorado.

Type	Colorado River					Rio Grande				
	Early		Recent		<i>P</i>	Early		Recent		<i>P</i>
	\bar{x}	SE	\bar{x}	SE		\bar{x}	SE	\bar{x}	SE	
Cottonwoods	11.2	2.1	9.2	1.7	NS	17.4	2.9	19.0	3.3	NS
Shrubs	9.5	1.8	10.1	2.1	NS	6.5	0.9	4.9	0.7	<.05
Hay Meadow	14.7	2.9	11.2	3.1	NS	68.6	7.0	54.5	6.3	<.03
Grassland	3.1	0.8	4.1	1.0	NS	0.9	0.6	3.1	1.4	<.05
Agriculture	5.5	1.6	5.1	2.6	NS	0.1	0.1	13.5	5.3	<.03
Developed	0.7	0.3	3.2	0.9	<.01	0.7	0.2	1.0	0.3	NS
River channel	9.3	0.7	8.8	0.8	NS	6.2	0.4	3.9	0.3	<.01
Standing water	0.1	0.05	2.3	0.8	<.03	1.0	0.3	1.2	0.3	NS

TABLE 3. Area occupied/segment (\bar{x} ha/km) by cottonwoods from early to recent sampling intervals along the Colorado River and Rio Grande, Colorado.

Segment	Colorado River					Rio Grande				
	Early		Recent		<i>P</i>	Early		Recent		<i>P</i>
	\bar{x}	SE	\bar{x}	SE		\bar{x}	SE	\bar{x}	SE	
Upper	2.3	0.6	0.2	0.1	.02	14.7	1.2	18.4	2.3	NS
Middle	24.0	4.2	19.6	2.3	NS	29.9	3.0	32.2	3.5	NS
Lower	7.8	3.1	7.4	2.2	NS	4.9	2.9	4.3	2.9	NS
Lowest	9.3	1.3	8.2	1.8	NS					

about 7.5–9.3 ha/km and declined at more modest rates.

Fifty-eight percent of the cottonwoods along the Colorado River were in the two younger maturity classes (Fig. 2). The percentage of young trees (< dm-dbh) declined almost 50% ($P < .01$) during the 25-year interval. Numbers of large trees (>7.6 dm) also declined dramatically ($P < .02$).

Hectares of cottonwoods were similar among all canopy-cover classes during the early sampling interval. However, by the recent sample interval, open stands increased 11%, whereas intermediate and closed stands declined 42% ($P < .01$) and 27% ($P = .05$), respectively (Fig. 2).

Hay meadow, the most abundant vegetation type along the Colorado River, declined 23.7% during the sample interval (Table 2) with the primary decrease occurring in the lower segment. Grassland occupied 5.7% of the area during early-year sampling but increased 31%. About 10% of the sampled area was in agriculture during both surveys. Developed land and standing water were initially minor but

increased to 10% of the total. Overall, river channel changed little, but variance among segments was evident; the channel widened in the two upstream segments and narrowed downstream.

Shrubs, primarily tamarisk, occupied 17–18% of the sampled riverbottom and increased slightly, primarily in the second segment. Shrubs occupied only 1.9–2.5 ha/km within the upper segment, >12.4 ha/km within the second and third segments, and 9.3 ha/km within the lower segment.

Rio Grande

Cottonwoods were moderately abundant within the upper segment of the Rio Grande, increasing 3.7 ha/km (24.9%), and were most abundant within the middle segment where they increased 2.3 ha/km (7.7%; Table 3, Fig. 1). They were absent within several downstream sample units, and estimated loss was 0.7 ha/km (13.8%). Initially, cottonwoods occupied 17.1% of the sampled area, increasing to 18.8% by the second survey (Table 2).

Small trees (<1.5 dm) represented 10.4% of

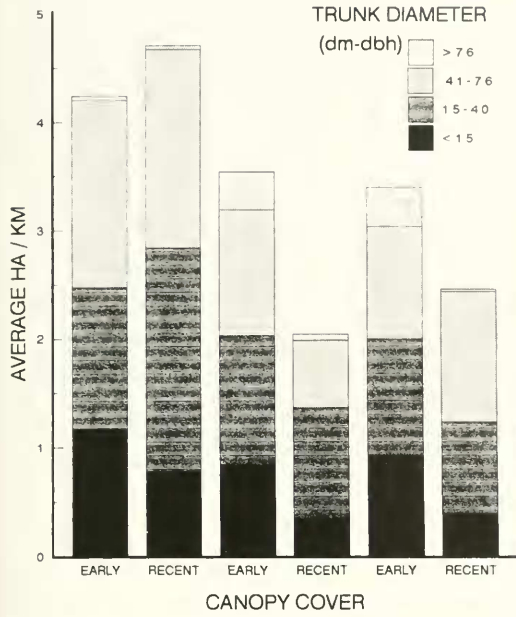


Fig. 2. Early to recent changes/sample in maturity class, and canopy cover of cottonwoods along the lower Colorado River, western Colorado.

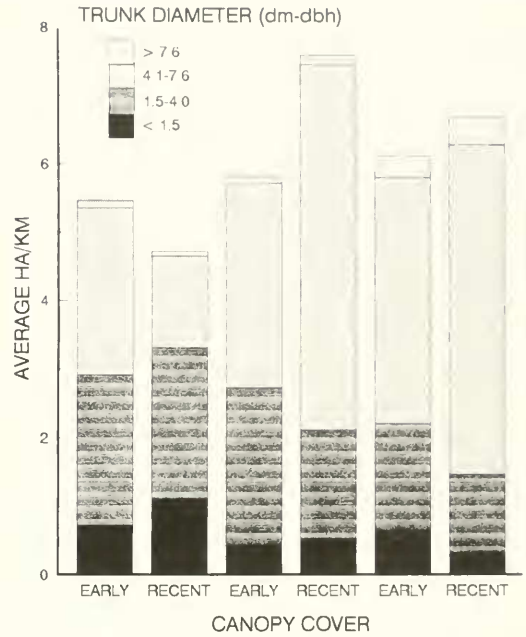


Fig. 3. Early to recent changes/sample in maturity class, and canopy cover of cottonwoods along the lower Rio Grande, southern Colorado.

the composition during both samples and increased 9.3% in occupied area (Fig. 3). Trees of intermediate size (1.5–4.0 dm) declined ($P = .13$) over the 36.7-year interval, giving way to the next larger (4.1–7.6 dm) maturity class that increased 27.2% ($P = .16$) (Fig. 3). This latter group dominated among maturity classes during both surveys. Large trees (>7.6 dm) represented only 3% of the total during both surveys and showed little evidence of increasing in occupied area.

Open stands initially occupied 31% of the timbered area and declined ($P = .25$) to 25% (Fig. 3). In contrast, stands of intermediate closure increased ($P = .02$) from 33 to 40%. Closed stands increased modestly ($P = .49$, 9%), representing 35% of the total during both surveys (Fig. 3).

Hay meadows dominated among vegetation types (Table 2), decreasing from 68 to 54% of the sampled area. Declines occurred primarily within the two upper segments. Initially, grassland was minor, but it increased, primarily within the upper segment. Only 2 of 20 samples originally contained cropland, but the proportion increased to 9 of 20 samples (0.1 to 13.4%).

Developed land and standing water were minor components in both early and recent

surveys. River channel decreased (36.7%) throughout the study area. Area occupied by shrubs was minor and estimated loss was 25% (Table 2).

DISCUSSION

Comparison of changes along the two rivers leads to greatest concern for habitats along the Colorado River, the much larger of the two (Table 1). The 25-year interval along the Colorado River was considerably less than that for the Rio Grande, but a 17.5% decline occurred in area occupied by trees. Development along the river increased dramatically and replaced many stands of trees.

Lack of natural reproduction and/or high mortality of young trees was indicated by a 50% reduction in stands of young trees along the Colorado River. Reduction of stands dominated by old trees, which provide primary habitat for cavity nesting wildlife, was also evident. However, rapid shifts toward more open stands, which indicated excessive mortality within stands, were more discouraging than changes in maturity structure. Thus, there were fewer and smaller stands and those remaining were more

open and occupied by intermediate maturity classes.

Losses of cottonwoods were especially dramatic (>90%) in the upper segment where occurrence was initially low. Expansion of urban areas, highway construction, and other developments were responsible for much of the riparian habitat loss in a relatively narrow valley that initially possessed limited riparian habitat and relatively rapid stream flows. Loss of trees to beaver (*Castor canadensis*) was noted and may be important, especially in the upper segments, since many stands of cottonwoods were confined to streambanks by valley relief.

Expansion of tamarisk was evident along lower reaches of the Colorado River within a broadened floodplain and slower stream flows. Increasing expansion of tamarisk severely limits opportunities for natural regeneration of cottonwoods and willows. Russian olive (*Elaeagnus angustifolia*) also is pioneering along the Colorado River. This species possesses a growth form of intermediate height and, like tamarisk, may form monocultures (Knopf and Olson 1984).

Stream flows along the Colorado River have not shown major declines in recent decades. Large impoundments and high-elevation diversions, primarily occurring during the last 50 years, have altered and reduced peak flow sequences on the Colorado and Gunnison rivers.

Extensive flooding occurred along the Colorado River in 1983-84, resulting in considerable natural reproduction of seedlings. However, infrequent flooding is not likely to offset the impacts of stream flow regulation, streamside developments, and invasions of exotic species. Vegetation conditions and changes along the Colorado River appear to be following the pattern of disrupted recruitment of native riparian phreatophytes occurring along many western rivers (Howe and Knopf 1991).

In contrast to changes documented along the Colorado River, riparian habitats along the Rio Grande were relatively stable during the sample interval, with an increase in area occupied by cottonwoods. However, several of the sample units within the lower segment contained few or no cottonwoods. Little evidence of seedling establishment was noted subsequent to increased stream flows during 1983-84, which raises concern for future trends. Stream flows averaged over 10-year intervals since 1890 showed little evidence of decline at Del Norte

in the west central portion of the San Luis Valley (Ugland et al. 1984, Vol. 1). However, upstream impoundments have reduced peak flows and altered patterns with stabilized increased volumes into late summer for irrigation. Flows downstream at Alamosa (Fig. 1) averaged about 30% of those at Del Norte, and average flows since 1930 have been about one-half of those from 1913 to 1930. Reduction in channel width was indicative of reduced and stabilized stream flows. Streambanks were dominated by perennial herbaceous vegetation, which provides limited opportunity for establishment of pioneering species such as cottonwoods and is indicative of moderately stable and slow stream flows through the relatively flat San Luis Valley. Increased farmland was the most pronounced land-use change along the Rio Grande, whereas little development occurred.

Shrubs (primarily willows) have not been major components along the Rio Grande in recent decades. Severe cold winters, due to high elevations (Table 1), may prevent invasions of tamarisk, which has developed as a streamside monoculture at lower elevations elsewhere along riparian systems in the Southwest. Russian olive was not yet invading the inventoried Rio Grande riverbottom.

Similar inventories of riparian vegetation changes and status were conducted along the South Platte and Arkansas rivers in the High Plains of eastern Colorado (Snyder and Miller 1991). Deterioration of habitat along the Arkansas River was much greater than along western rivers in Colorado. However, conditions along the Colorado River seemed to be deteriorating more rapidly than along the South Platte River. There was also much less riparian habitat along western rivers, making that which remained of greater importance. Sampling of changes between two points in time may not give an accurate assessment of long-term trends. A third inventory of these same sample units is recommended in the near future.

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